Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

REMOTE SENSING WITH DRONES

YNCenter Video Conference

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08-28-2015

Drone remote sensing

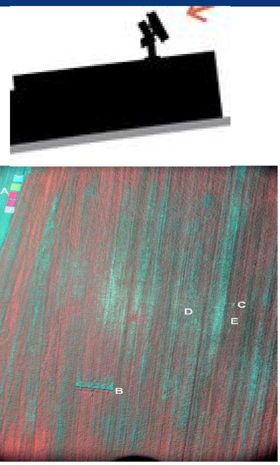
- It was first utilized in military context and has been given great attention in civil use in recent years.
- Three Unmanned Aerial Systems (UAS) components:

Source: Colomina et al. (2014)

Unmanned Aerial Vehicle

Source: Jaime et al. (2014)

Ground Control Station



Source: Hunt et al. (2010)

Communication data link

- **UAS classification**
- aerial platform (size and weight, endurance, aerodynamics, etc.);
- the system operation (mission range or flying altitude, nature of its application, etc.)
- **Cameras**
- RGB; multi-spectral; hyperspectral and thermal-imaging camera

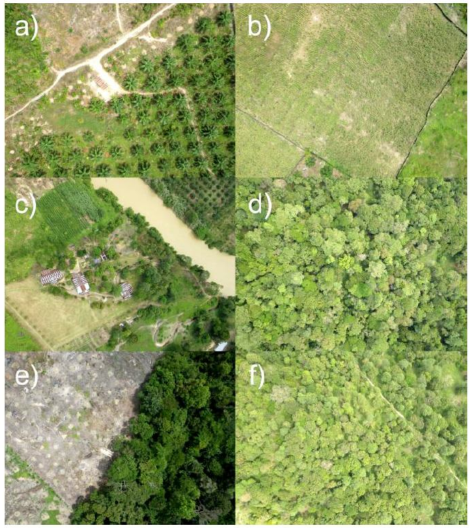
Common and/or representative multispectral cameras for UAS.

Manufacturer and model	Resolution (Mpx)	Size (mm^2)	Pixel size (μm)	Weight (kg)	Spectral range (nm)
Tertracam MiniMCA-6	CMOS 1.3	6.66 ×5.32	5.2 ×5.2	0.7	450–1050
Quest Innovations Condor-5 UAV-285	CCD 1.4	10.2 ×8.3	7.5 ×8.1	0.8	400–1000

Source: Colomina et al. (2014)

Pros and cons of UAV

- **Pros:**
- High spatial and temporal resolution
- Manually controlled (altitude, route…) not labor-intensive
- Rarely affected by cloud cover
- Cost-effective
- Flexibility



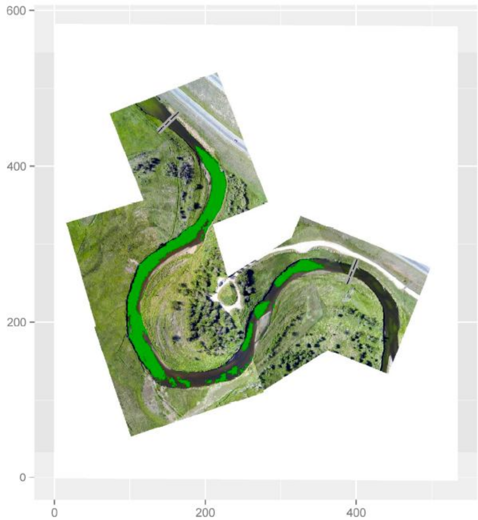
Source: Lian et al. (2012)

- **Cons:**
- Sensitive to wind
- Poor geometric and radiometric performance
- Short flight endurance

Source: Colomina et al. (2014)
Jaime et al. (2014)

Application of UAVs

- High resolution of digital elevation model
- Precision agriculture
- Water plant monitoring
- Forest inventory (gap vs biodiversity)
- Atmospheric science (aerosol)



Source: Flynn et al. (2014)

Source: Lian et al. (2012)

Source: Getzin et al. (2012)

Objectives

- Exploring the image processing and analyzing techniques based on the data we have.
- Finding new points.

Data introduction

Name	Location	Time	Band	Point Cloud
Goshen	CT, US	Mar, 2014	R, G, B	Yes
Goshen_Nov_RGB	CT, US	Nov,2014	R, G, B	Yes
Goshen_Nov_NIR	CT, US	Nov, 2014	G,R, NIR	Yes
Cheshire	CT, US	Apr, 2015	G, R, Red edge, NIR	No
Maryland State Park	MD, US	Mar, 2015	No	Yes

Goshen

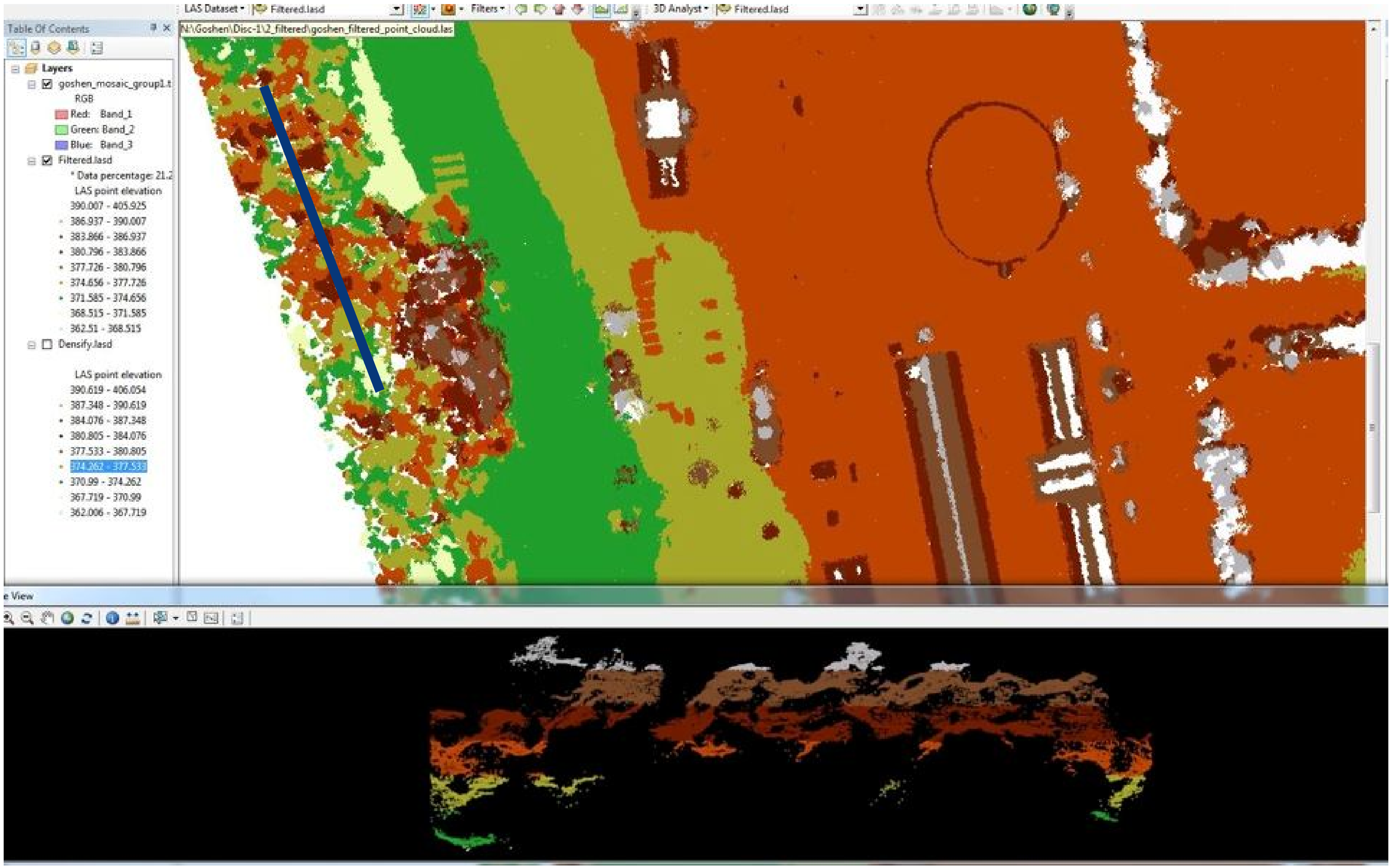
Figure 1 | Goshen image

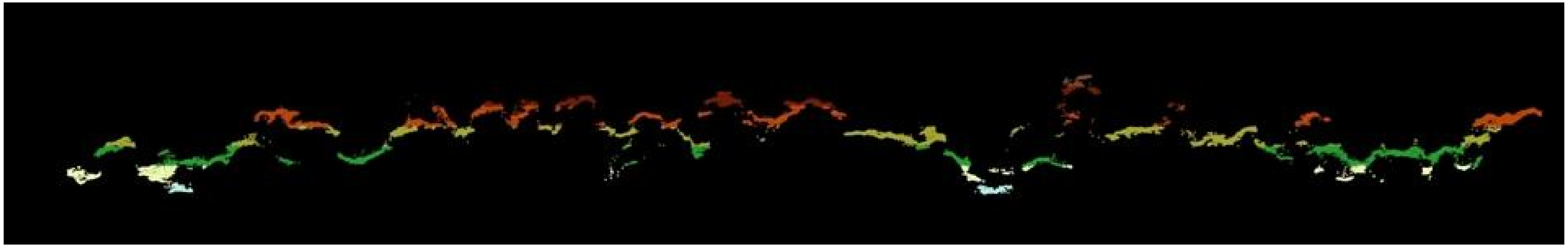
3D map in ENVI

3D map in ArcGis

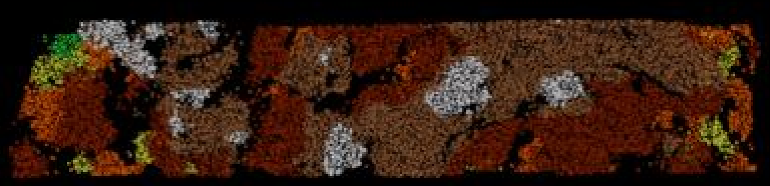
The boundaries of road and trees are not clear.

Point Cloud Visualization in ArcGIS





X-Z Plane



X-Y Plane X-Z Plane

Goshen November

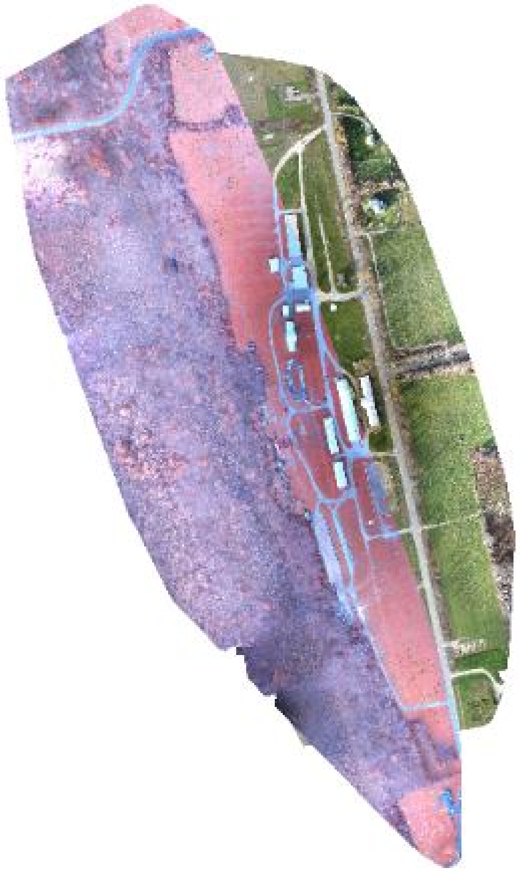
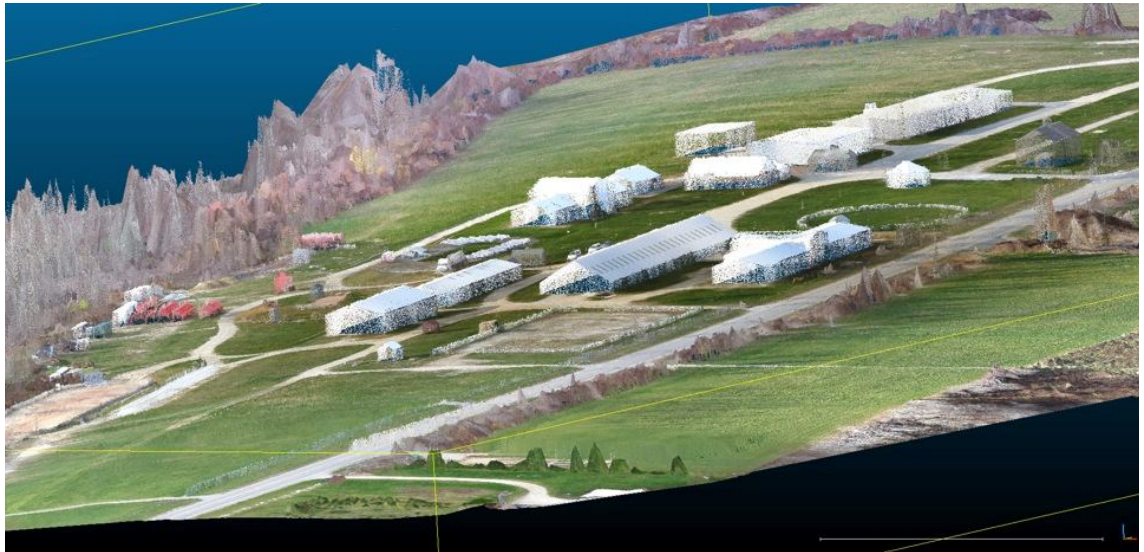
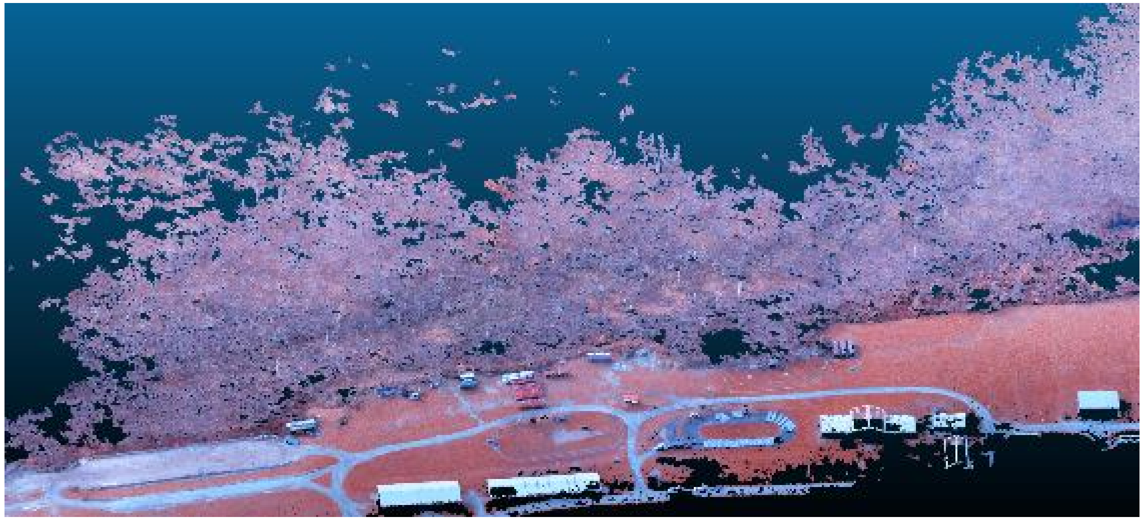


Figure 2 | Goshen images taken in Nov, 2014

3D view of Goshen images in CloudCompare



3D view of Goshen images (NIR)

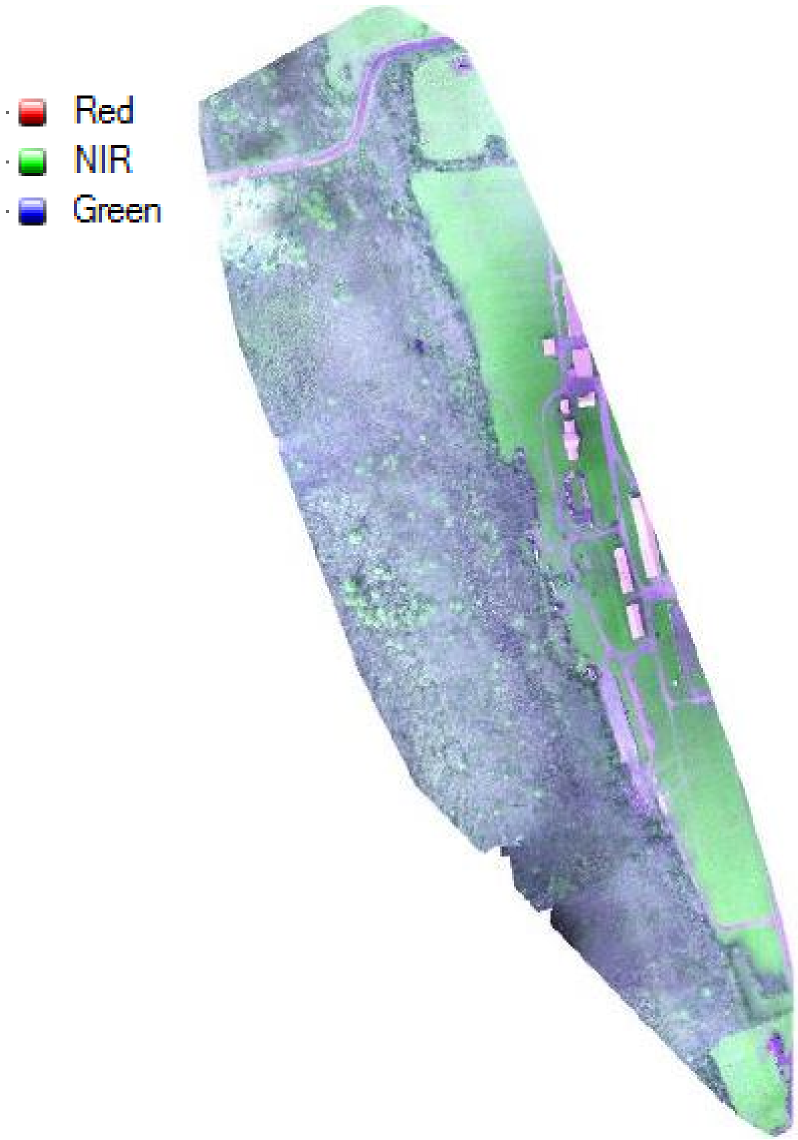


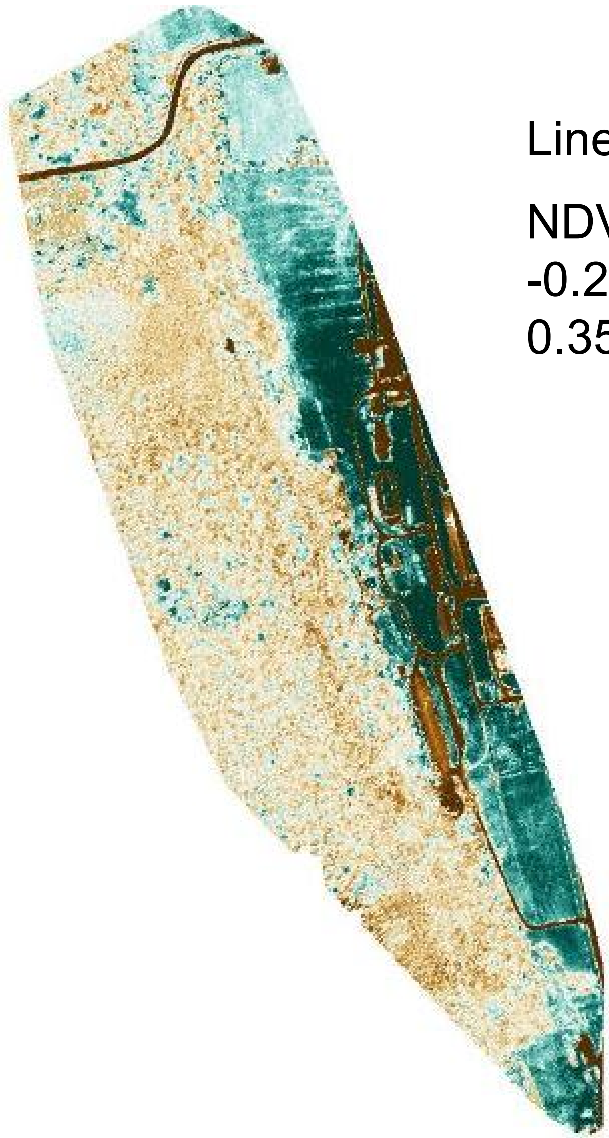
Point cloud – remove things

Original image

Translated image

NDVI Goshen November

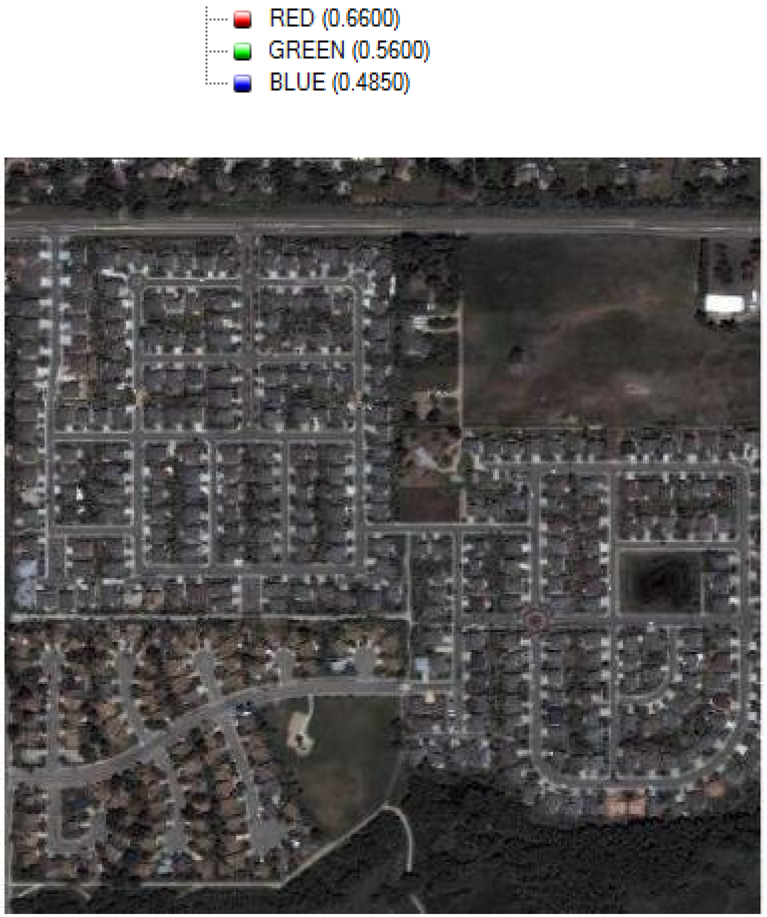


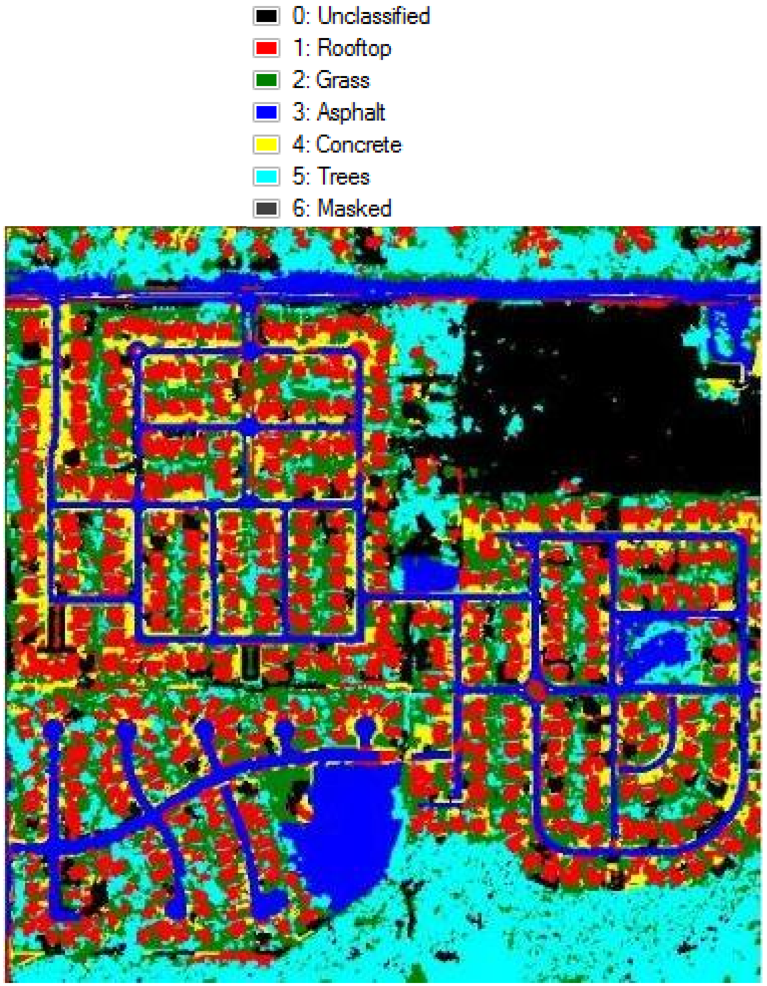


Linear 5%

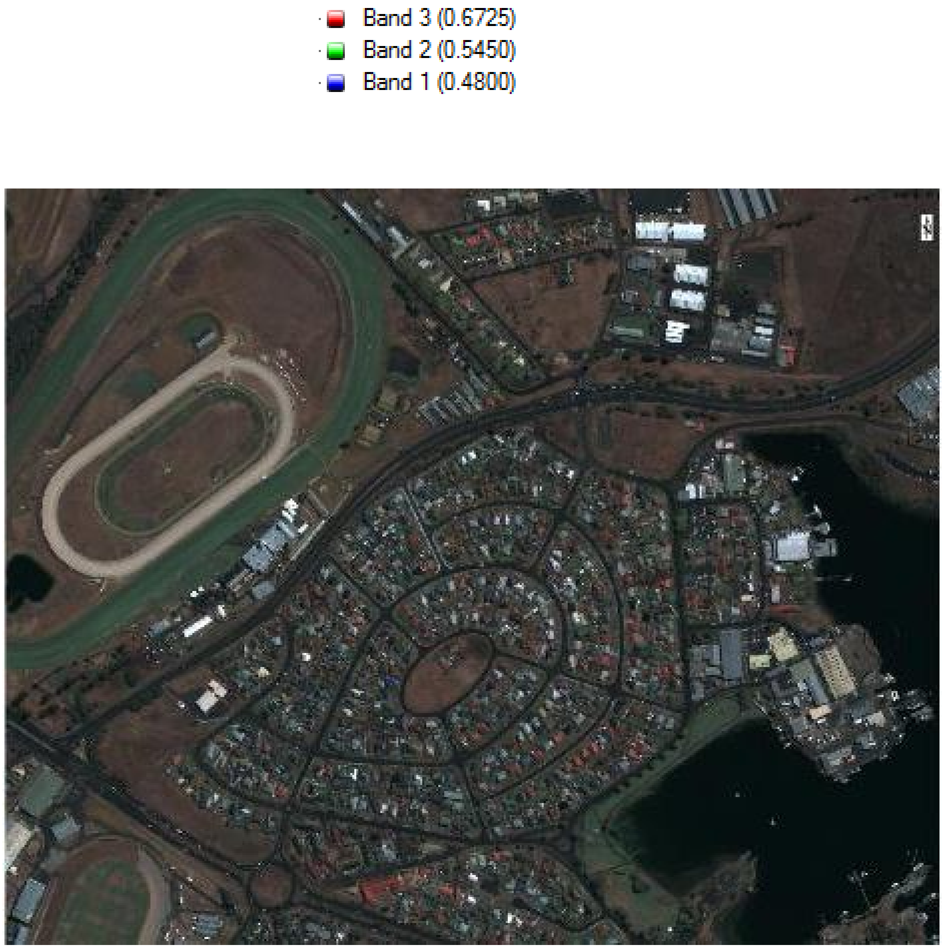
NDVI range:
-0.2269
0.3561

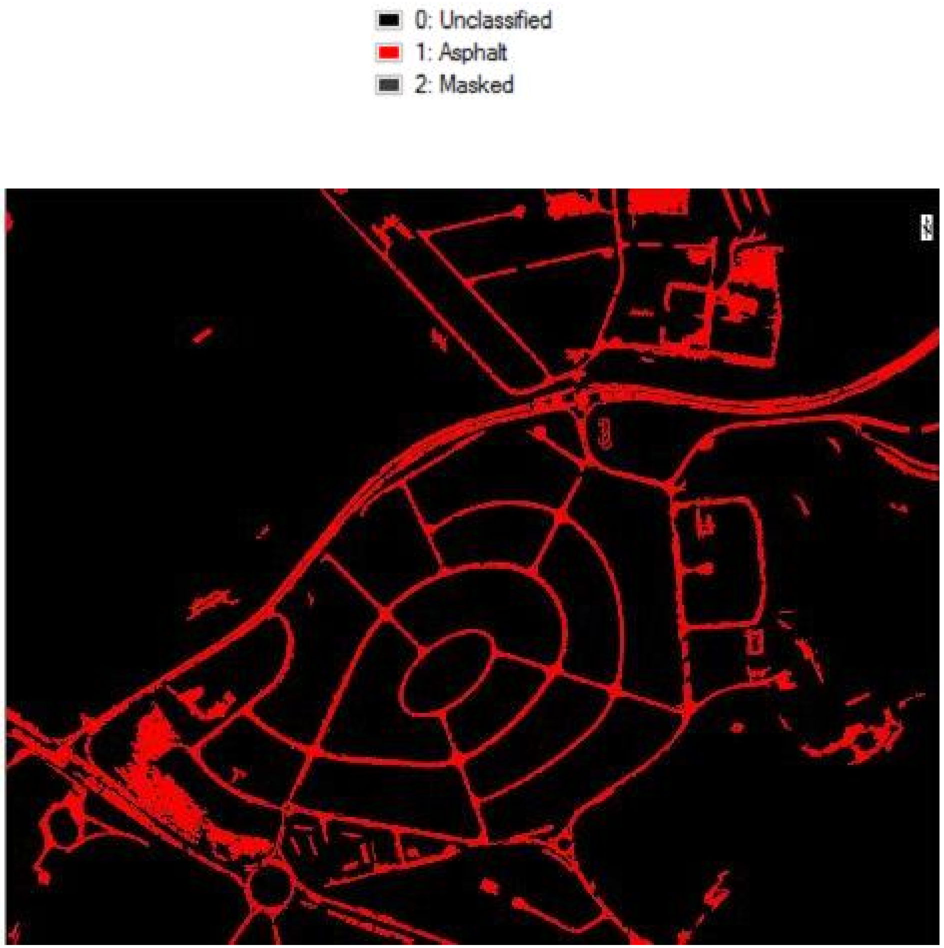
Feature extraction module in ENVI





Example-based Classification





Rule-based Classification

Goshen- Extract roof (red)

Feature extraction on Goshen NIR image

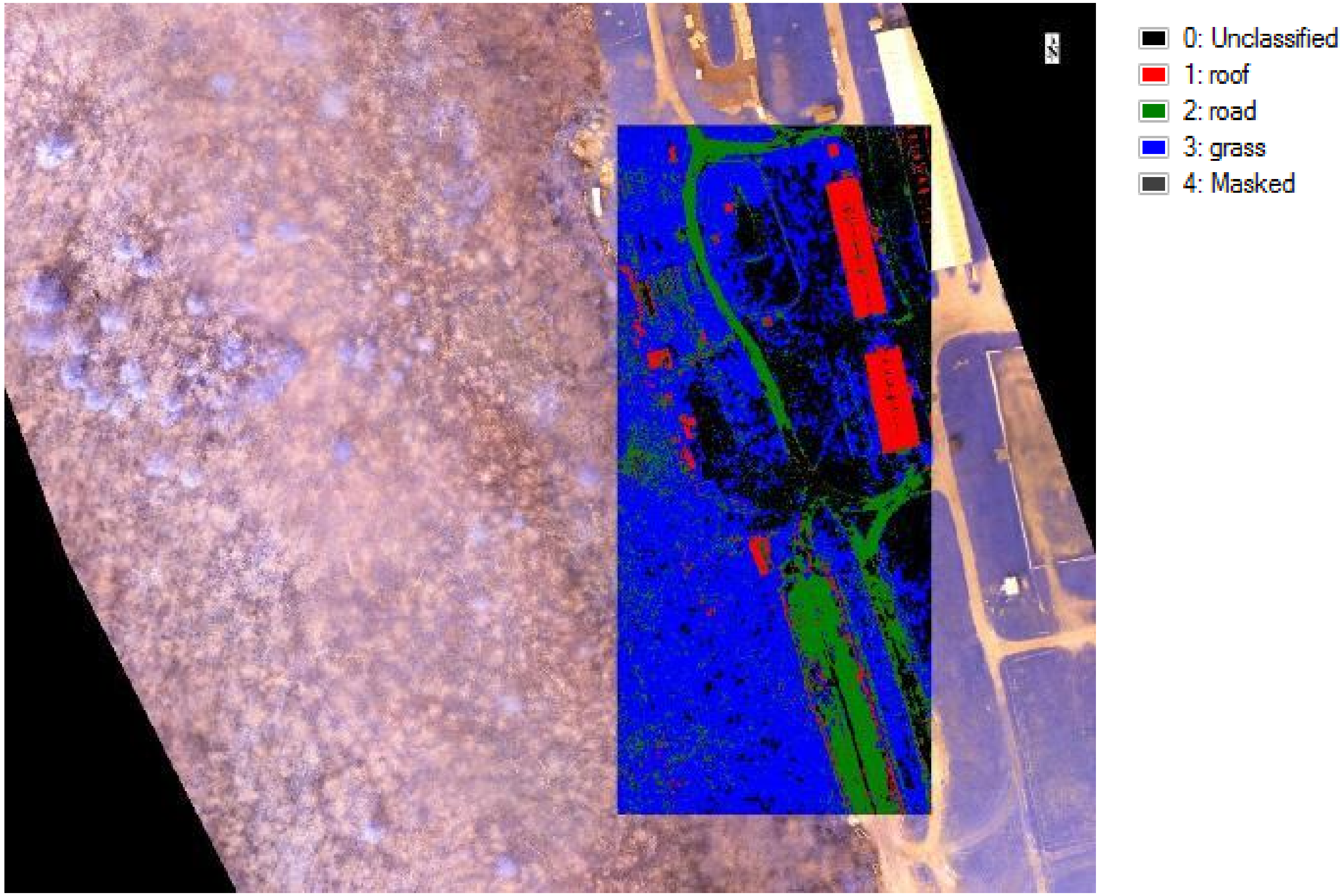
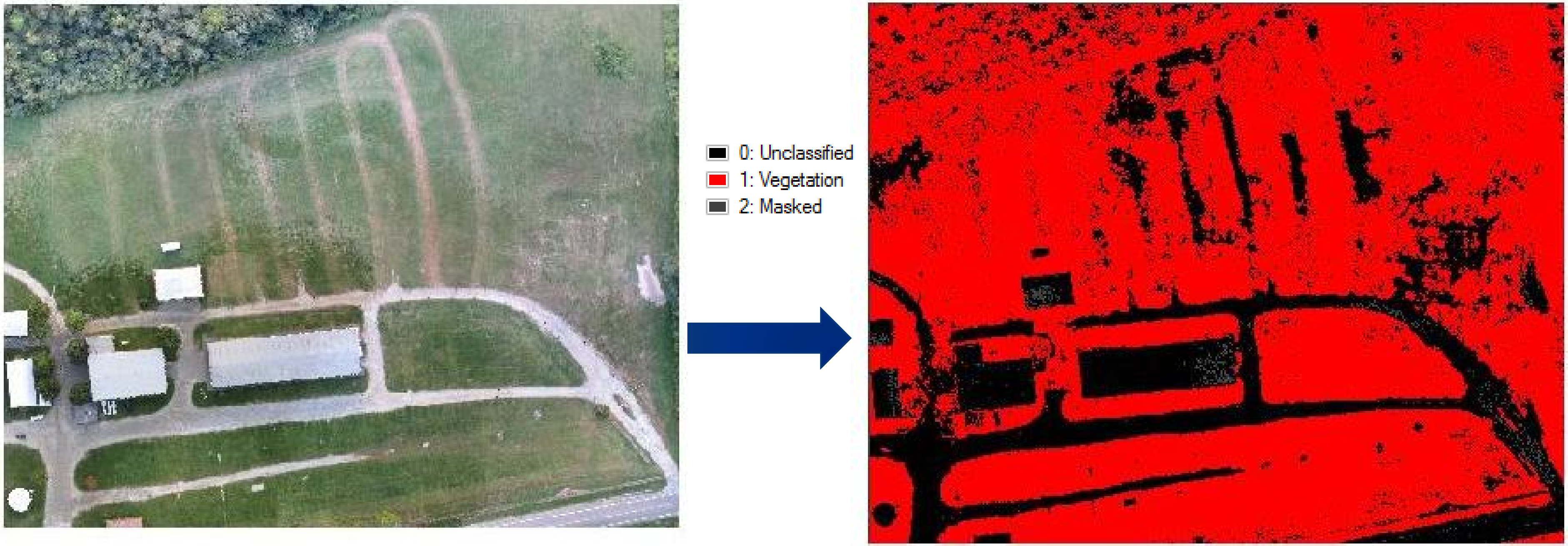


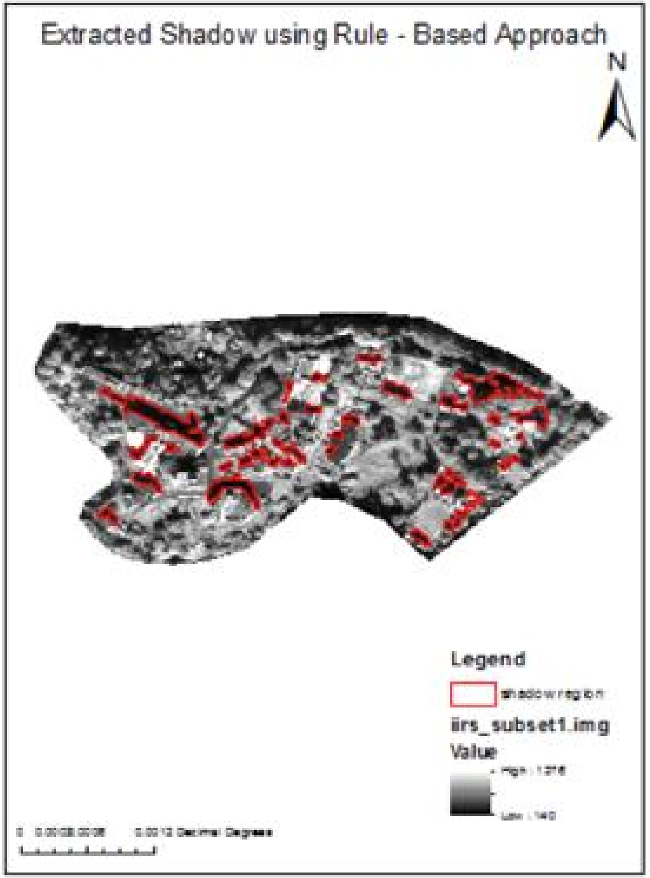
Figure 3 | Example-based classification of roof

Rule-based feature extraction
vegetation



Rule:
spectral mean of band 1(red): 57 to 160
spectral mean of band 2 (green): 57 to 149

Extract shadow



Source: Raju et al, (2014)

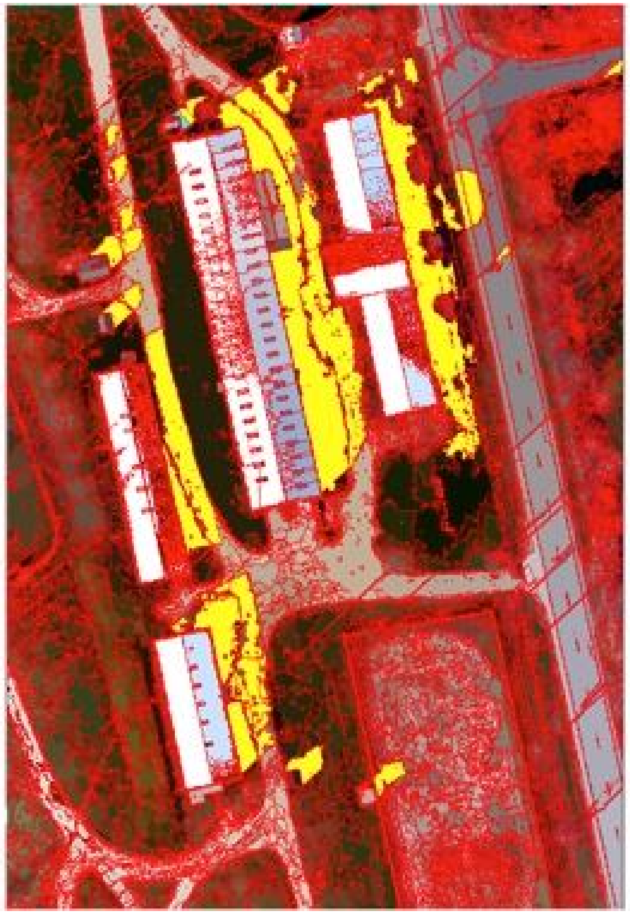
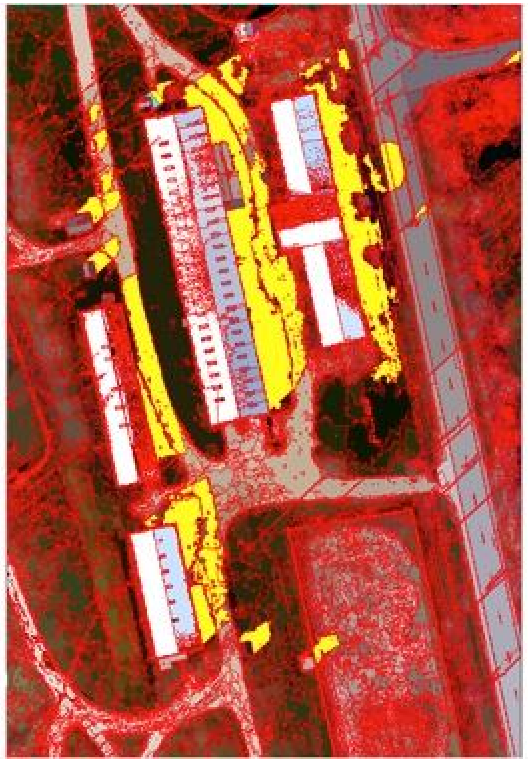


Figure 4 | Rule-based classification of shadow for Goshen data (yellow represents shadow)

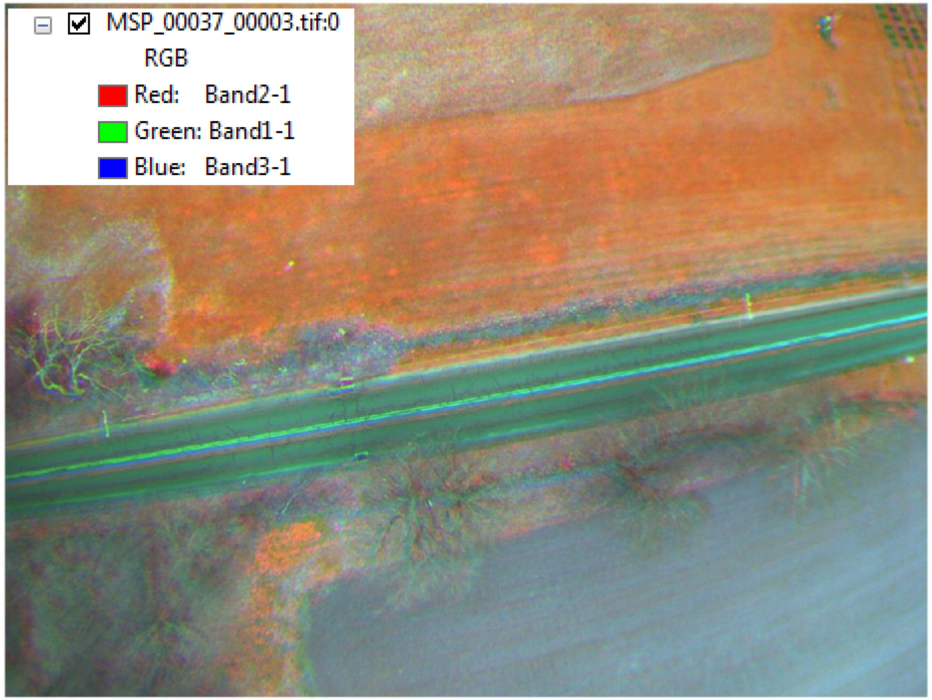


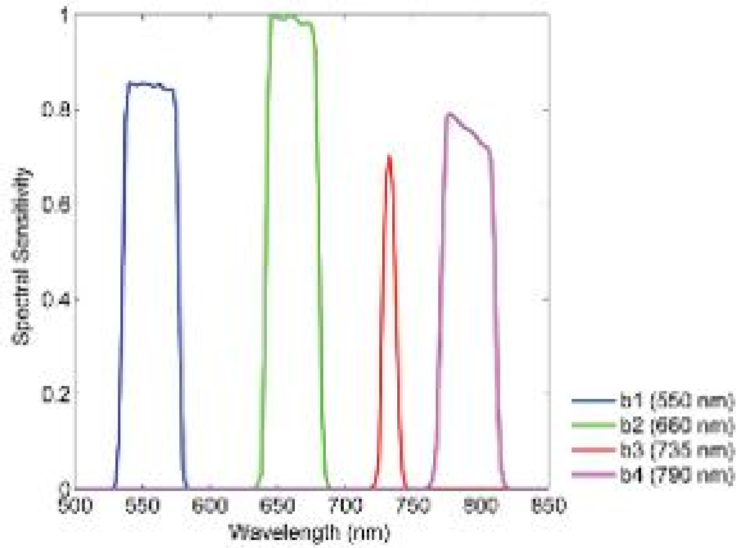
Suppose building 1's height is unknown and that of building 2 is known (suppose it is 10m).

Using measuring tool in ENVI:
Sl_{un}= 20.56m, sl= 14.04m
H_{un}=(20.5648*10)/14.0357=14.65m

Cheshire image processing in Pix4D

- Camera: multiSPEC4C_3.6_1280*960
- (**Exiftool**)
- Green, Red, Red Edge, NIR (4 bands)





Flight path (Pix4D)

Figure 5 | Flight path of Cheshire in Google map

Cheshire

Image bands separation (**gdal_translate**)

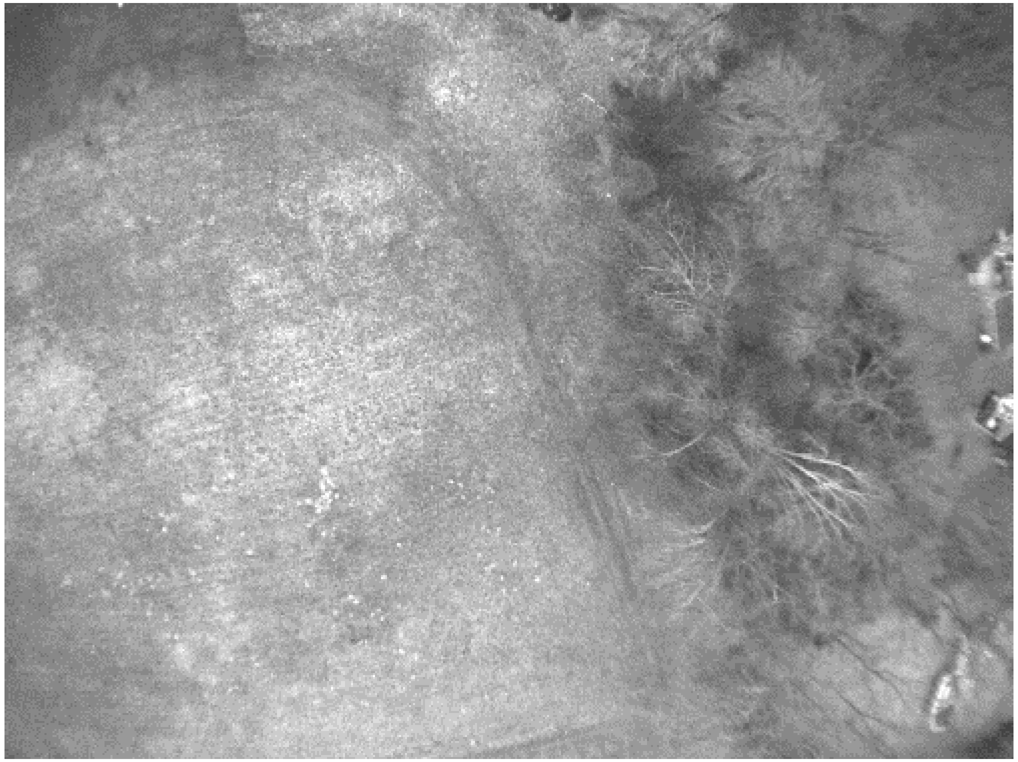
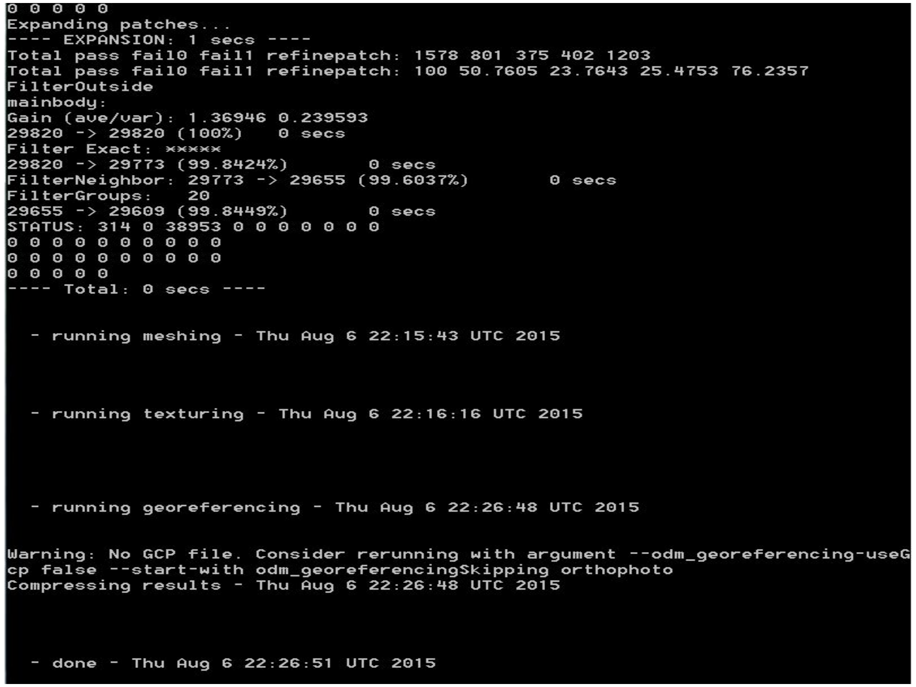
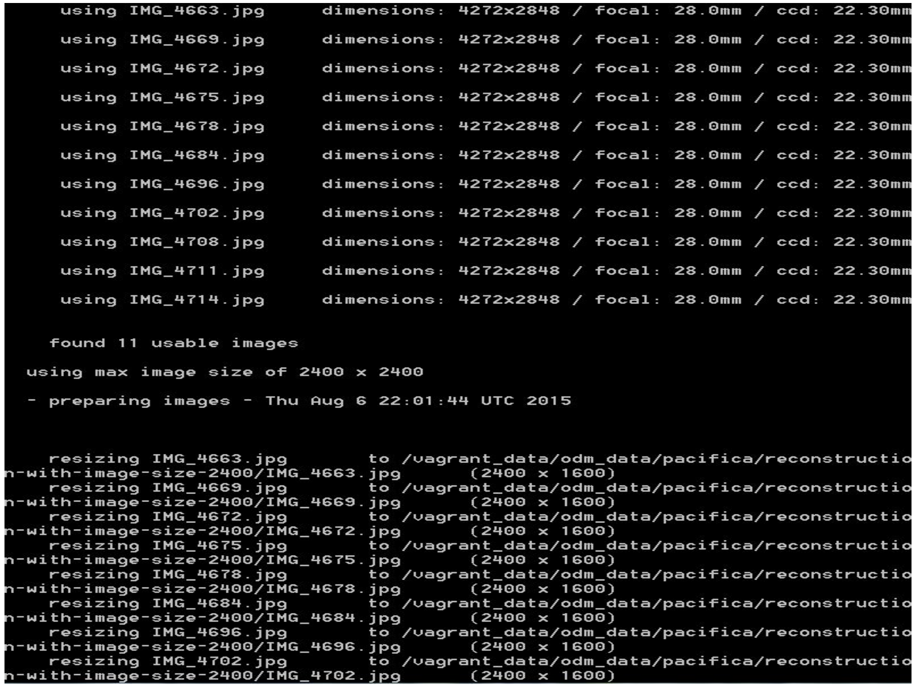


Figure 6 | Merged image of Cheshire red band

OpenDroneMap

- Install virtual machine (GitHub) and enter Linux command
- Input: UAV raw images (with geographic information)
- Output: point cloud; meshing data
- Example: Goshen November RGB Images (6 images)





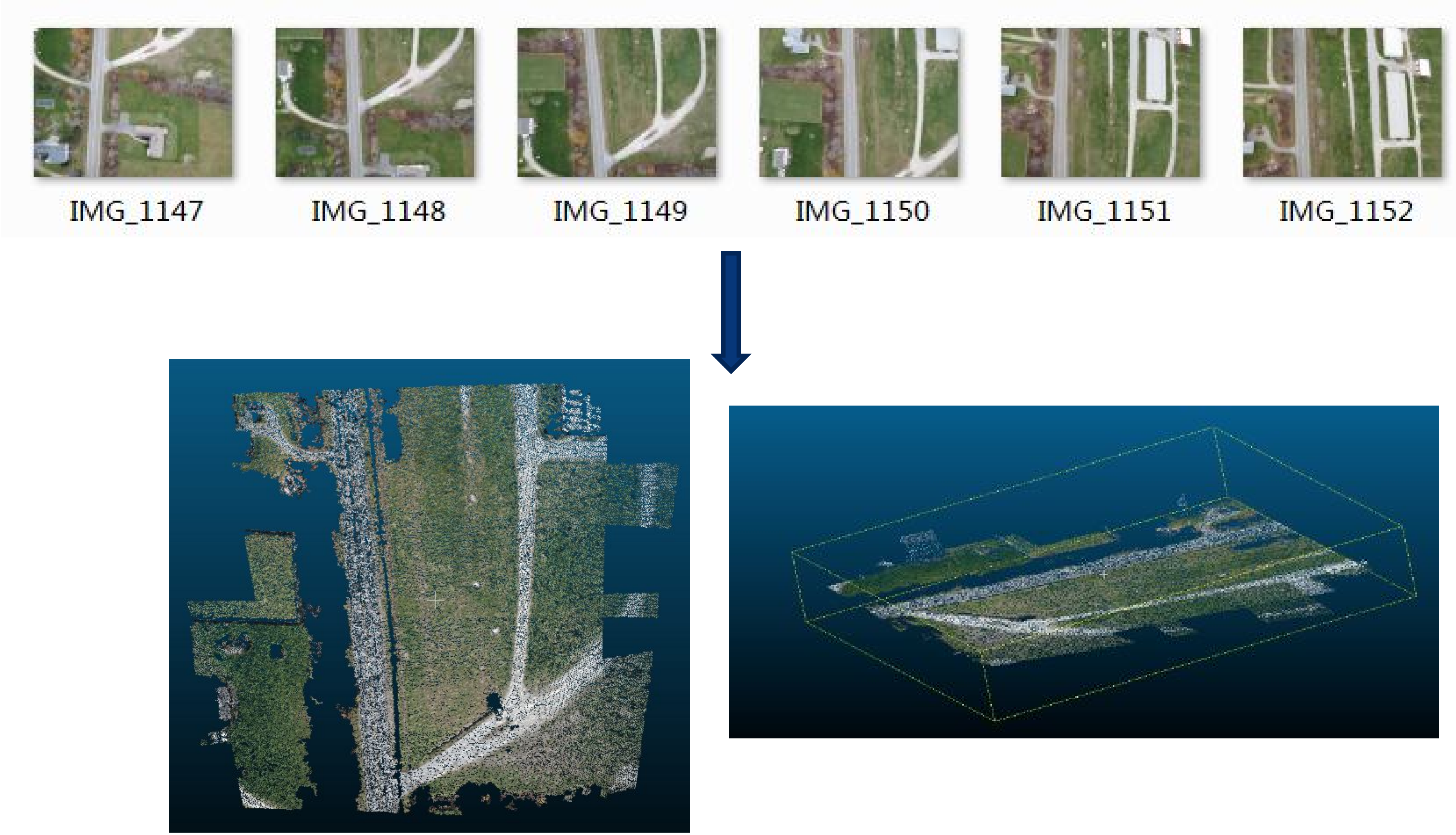


Figure 7 | Cloud point data generated from OpenDroneMap

Next work

- New index
- Image interpretation combined with field measurement
- New function exploration of UAV softwares

Table 1 Spectral indices used in the present study calculated using MCA sensor set of bands

Index	Equation	References
Chlorophyll absorption ratio	$CAR = \frac{\lvert(R700-R500)/670 \cdot R670 + R670 - ((R700-R500)/670 \cdot 550 + R550)\rvert}{\sqrt{((R700-R500)/670)^2+1}}$	Bruge and Leblanc (2001)
Chlorophyll absorption ratio	$CARI = CAR*\frac{R700}{R670}$	Kim et al. (1994); Bruge and Leblanc (2001)
Greenness index	$GI = \frac{R550}{R670}$	Zarco-Tejada et al. (2005a, b)
Green normalized difference vegetation index	$GNDVI = \frac{R800-R550}{R800+R550}$	Gitelson and Merzlyak (1998)
Modified chlorophyll absorption in reflectance	$MCARI = [(R700-R670)-0.2*(R700-R550)]*(R700/R670)$	Daughtry et al. (2000)
Modified chlorophyll absorption in reflectance	$MCARI1 = 1.2*[2.5*(R800-R670)-1.3*(R800-R550)]$	Haboudane et al. (2004)
Modified chlorophyll absorption in reflectance	$MCARI2 = \frac{1.2*[2.5*(R800-R670)-1.3*(R800-R550)]}{\sqrt{(2*R800+1)^2-(6*R800-5\sqrt{R670})-0.5}}$	Haboudane et al. (2004)
Improved SAVI (soil-adjusted VI) with self-adjustment factor L	$MSAVI = \frac{1}{2}*\left(2*R800+1-\sqrt{(2*R800+1)^2-8*(R800-R670)}\right)$	Qi et al. (1994)
Modified simple ratio	$MSR = \frac{(R800/R670)-1}{\sqrt{(R800/R670)+1}}$	Chen (1996)
Modified triangular VI	$MTVI3 = 1.2*[1.2*(R800-R550)-2.5*(R670-R550)]$	Rodríguez-Pérez et al. (2007)
Normalized difference vegetation index	$NDVI = \frac{R800-R670}{R800+R670}$	Rouse et al. (1974)
Optimized soil-adjusted vegetation index	$OSAVI = (1+0.16)*(R800-R670)/(R800+R670+0.16)$	Rondeaux et al. (1996)
Simple ratio index	$SRI = \frac{R800}{R550}$	Jordan (1969)
Photochemical reflectance index	$PRI = \frac{R570-R530}{R570+R530}$	Fuentes et al. (2001); Gamon and Surfus (1999)
Renormalized difference VI	$RDVI = \frac{R800-R670}{\sqrt{R800+R670}}$	Reujean and Breon (1995)
Transformed chlorophyll absorption in reflectance	$TCARI = 3*[(R700-R670)-0.2*(R700-R550)*(R700/R670)]$	Haboudane et al. (2002)
TCARI/OSAVI	$TCARI/OSAVI = \frac{3*[(R700-R670)-0.2*(R700-R550)*(R700/R670)]}{(1+0.16)*(R800-R670)/(R800+R670+0.16)}$	Haboudane et al. (2002)

Source: Javier et al. (2012)

Thank you